

Recognition of Diagnostic Acoustic Signatures in Shelf and Slope Deposits: The STRATAFORM California Site

Michael E. Field
U. S. Geological Survey
University of California, Santa Cruz, CA 95064
phone: (831) 459-3428 fax: (831) 459-3707 email: mfield@usgs.gov

James V. Gardner
U. S. Geological Survey
345 Middlefield Rd, Menlo Park, CA 94025
phone: (650) 329-5469 fax: (650) 329-5411 email: jvgardner@usgs.gov

David B. Prior
Department of Oceanography
Texas A & M University, College Station, TX 77843
phone: (409) 845-3651 fax: (409) 845-0056 email: prior@ocean.tamu.edu

Glenn Spinelli
Dept of Earth Sciences
University of California, Santa Cruz, CA 95064
phone: (831) 459-3431 fax: (831) 459-4882 email: gspinelli@usgs.gov
Award # N0001499F0007

LONG-TERM GOALS

One of the major goals of the STRATAFORM Project is to gain a better understanding of how strata form and how they combine to form characteristic stratigraphic sequences, such as drapes, aprons, wedges, sigmoids, and other characteristic geometries. An essential part of this understanding is the analysis and interpretation of surface features and deposits in the upper 50 m of the shelf and slope to provide information on the mechanism of sediment transport and deposition. Interpreting the signatures of various processes in surface and near-surface deposits provides a critical link between knowledge gained from measuring physical processes that are dominant over time spans from the duration of a single event to several years, and those inferred from seismic-reflection data that may represent 10^2 to 10^4 years. Towards these ends, we have been testing some of the concepts of sequence stratigraphy.

OBJECTIVES

Our objectives are to identify the types of sediment signatures that occur in high-resolution seismic-reflection and sidescan-sonar records from the California continental margin, correlate them with the causative process (flood sedimentation, turbidity flow, slow hemipelagic drape, slope currents, etc.) that formed the deposits, and identify the relative abundance and significance of slope- and shelf-sediment signatures. These signatures can then be correlated with results from other STRATAFORM investigations and major patterns can be related to fluctuating sediment sources, sea levels, and climate.

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Our specific objectives for FY1999 included the following:

- Continue our studies of continuity, extent, vertical history, and overall significance of gullies on the slope.
- Expand studies of instability mechanisms to other margins to address the critical factors that cause some seafloor areas to remain stable and others to undergo failure.
- Begin preparation of a manuscript to interpret the styles of sedimentation and the amount of sediment deposited during the last transgression and present-day highstand of sea level.
- Continue studies to define the nature and style of sediment deposition and deformation in the vicinity of a large, active anticline on the outer shelf.
- Present findings at an international meeting in Japan and at national meetings and workshops on slope gully systems, slope sediment-gravity deposits, reflector geometry, and inferred sediment processes.

Sediment is deposited on shelves and slopes in distinctive packages or sequences that bear similarities at many sites around the world. The exact processes that form these sequences are not well understood. The STRATAFORM project seeks to integrate studies of sediment transport with observations of sediment deposition and with computer models to develop a better understanding of how sediment sequences originate on continental margins.

APPROACH

Our study contributes as an integral part of STRATAFORM, specifically the investigation of small-scale topography on the shelf and slope. We have employed high-resolution seismic-reflection data and side-scan sonar to document the presence and distinctive characteristics of marine sediment-gravity deposits and record the diagnostic geometric patterns of shallow subsurface strata on the shelf and slope.

WORK COMPLETED

Our studies of key scientific issues in the STRATAFORM area have been based on analyses of high-resolution acoustic profiles and sidescan data from two major research cruises using the Hunttec DTS System and a Datasonics SIS-1000. Our research focus has been directed toward the following science topics, all of them key to addressing the over-arching goals of the project and the STRATAFORM Program:

- The California shelf is underlain at shallow depths by a major unconformity which appears to represent a significant hiatus in sediment accumulation.
- 2. The Humboldt Slide Zone is a complex feature formed principally by limited-movement shear of sediment at depth. Late stage sediment failures and flows appear to cap the structure.
- 3. The stratigraphy of the shelf and upper slope consists of a lowstand surface of erosion overlain by transgressive surface of erosion followed upwards by transgressive and high-stand deposits..
- Gullies are a major slope feature on the Eel river slope and on many slopes world-wide. We have found that the gullies initially formed *prior* to the last lowstand of sea level. Since that time they have gone through several periods of growth and infill. At present they show little evidence of being active and appear to be infilling
- Uplift on an upper slope anticline concurrent with deposition has resulted in a ridge and swale terrain. Strata composing the ridges and underlying the swales are truncated and locally tilted, and are thought to result from a complex interplay of sedimentation and tectonic uplift.

RESULTS

Our understanding of slope gullies is summarized below from “Geomorphic Evolution of a Network of Continental Slope Gullies on the Northern California Margin” (G. Spinelli and M. Field, submitted to *Sedimentary Geology*).

Slope gullies occur on the northern California margin both on the surface and in the subsurface. The network of gullies extended farthest upslope, and the gullies exhibited maximum relief, just prior to the LGM lowstand of sea level. At that time, approximately 10 km of non-gullied outer shelf and upper slope stretched between the coastline and the gully network; thus the slope gullies were not connected to a sub-aerial or shelf drainage network. The processes that formed the gullies were most effective prior to the LGM. As sea level rose during the deglaciation, the gullies filled with sediment over a period of several thousand years. Gully forming processes have been inactive, or relatively weak, since the LGM. The gully infilling process is presumably ongoing today because the number of gullies on the modern seafloor is half the number in the subsurface.

The specific processes that form, maintain, and infill the slope gullies are not understood. It is clear from studies of modern slope sediment and processes that dispersive nepheloid sedimentation is an important process shaping the continental slope (Walsh and Nittrouer, 1999). It is also evident from Huntect DTS lines of the lower slope that sediment gravity flows have occurred on the slope and in the channels fed by gullies. Processes on the upper slope that may remobilize nepheloid-dispersed sediment and move it downslope in gullies include oceanographic currents and breaking internal waves. As yet, no evidence has been obtained to document a gully shaping mechanism.

Finally, we recognize a distinct correlation between gully formation/infilling and sea level position. The gullies were larger and more abundant and were probably initiated during falling and low sea level conditions, a time of increased sediment delivery to the coasts and more energetic conditions at the water depth of the gullies. In contrast, the gullies decreased in size and number as sea level rose and sediment sources retreated farther landward, resulting in sedimentation that was more dispersive and a less energetic environment at the greater water depths of the gullies.

IMPACT/APPLICATIONS

Gullies are common on many continental slopes around the world, and we believe that our recent findings may have application for understanding their role in sediment transport and evolution of slopes. On the Eel River Basin slope off northern California, approximately one-half of the sub-surface gullies have no expression on the seafloor, as they have completely filled with sediment following the last glacial maximum lowstand of sea level. The process or processes responsible for gully growth and maintenance prior to the last glacial maximum lowstand of sea level effectively ceased following the lowstand, when the gullies head in deeper water (~300 m water depth) and lie farther from potential sediment sources. Erosion is not evident in the gully bottoms, therefore gully growth was likely due to the persistent inhibition of sediment deposition in the gullies or preferential sedimentation on gully interfluvies. As the gullies increased in relief, the heads of the gullies extended up the slope toward the shelf break. At all times, a minimum of 10 km of non-gullied upper slope and outer shelf stretched between the heads of the gullies and the paleo-shoreline; the gullies did not connect with a sub-aerial drainage network at any time. Gully growth occurred when the gully heads were in relatively shallow water (~200 m paleo water depth) and were closest to potential sediment sources.

Our findings are significant to sequence stratigraphic models in two ways. First, the presence of relatively thick transgressive deposits adjacent to small coastal drainage basins indicates that sequence stratigraphic concepts operate differently on the narrow, high-relief, high-sediment load areas characteristic of Pacific-style margins where base levels rapidly adjust to sea level shifts. Changes in base level seem to be quickly accommodated, although sedimentation remains more-or-less continuous, with only subtle changes associated with shifts in sea level. Second, accommodation space varies along margins as well as across margins. On margins affected by local or regional tectonics, the processes of uplift and downwarp locally create and destroy space as rapidly as do shifts in sea level. Fold axes on the northern California shelf and slope strike normal to sub-parallel to the coastline, thus continuing uplift and downwarp along these axes destroys and creates accommodation space, respectively. The result is a shelf-slope depositional unit that is discontinuous and of variable thickness.

TRANSITIONS

Our results are being used directly by other ONR investigators in the STRATFORM Project to calibrate numerical models of sequence stratigraphy, compare analyses of short-term rates of sediment accumulation, analyze geologic structures and fluid escape features, and interpret the shallow part of MCS profiles.

RELATED PROJECTS

Our studies of late Quaternary stratigraphy and sedimentation on the Eel shelf and slope are integrated with colleagues:

- Developing computer simulations of the Eel River continental margin (J. Syvitski, U Colorado; D. Swift, Old Dominion U.; and M. Steckler, Lamont Doherty Earth Obs);
- Measuring sediment accumulation rates for comparison with our maps of sediment sequences (C. Nittrouer, U. Washington; and C. Alexander, Skidaway Inst.Ocean)
- Analysing deep structure and stratigraphy in the Eel River basin to provide an integrated interpretation (C. Fulthorpe and J.Austin, U. Texas; and D. Orange, UC Santa Cruz).

PUBLICATIONS

Field, M., Berne, S., Colella, A., Nittrouer, C., and Trincardi, F., 1999, Conference stresses relevance of marine strata to today's issues. EOS, transactions, Amer. Geophysical Union, v. 80., no. 12, p.135.

Field, M. E., Gardner, J. G. Prior, D. B., 1999, Geometry and significance of stacked gullies on the northern California slope. *MARINE GEOLOGY*, v. 154 p. 271-286.

Field, M., Berne, S., Colella, A., Nittrouer, C., and Trincardi, F., 1998, Editors, STRATCON '98: Strata and Sequences on Shelves and Slopes. Program and Abstract Volume, SEPM Research conference, Sicily IT, Sept, 1998. Society of Sedimentary Geology, Tulsa, OK.

Friedlander, A., Boehlert, G. W., Field, M. E., Mason, J. E., Gardner, J. V., and Dartnell, Peter, accepted, Sidescan sonar mapping of benthic trawl marks on the shelf and slope off Eureka, CA. Jour. Fisheries.

Gardner, Prior, D B., Field, M. E., 1999, Humboldt Slide- A large shear-dominated retrogressive slope failure. *MARINE GEOLOGY*, v. 154, p. 323-338.

Hughes Clarke, J.E., Gardner, J.V., Torresan, M., and Mayer, L.A., 1998, The limit of spatial resolution achievable using a 30-kHz multibeam sonar: model predictions and field results. *Ocean '98 IEEE OES Conference Proceedings*, v. 3, p. 1823-1827.

Prior, D. B., and Hooper, J. R., in press, Seafloor engineering geomorphology: Some recent achievements and future directions. *JOURNAL OF GEOMORPHOLOGY*

Prior, D.B, van der Spek, A.J. F., Tutton, M. A., Buleka, J., Abrahams, J., Kuna, G., van der Valk, L., Woods, M., and Dennis, A., in press, High energy transport processes--from the coast to deep water--Huon Gulf, Papua New Guinea, special volume of *MARINE GEOLOGY*

Yun, J. W., Orange, D. L., Field, M. E., 1999, Gas distribution off shore northern California and its link to submarine morphology. *MARINE GEOLOGY*, v. 154, p.357-368.

ABSTRACTS

Field, M. E., 1999, Sedimentary response of Pacific-style margins to high frequency sealevel change: the record from California. *Land-Sea Link in Asia: K.O Emery commemorative international Workshop*, Tsukuba, Japan, April, 1999. P 336-340.

Foland, S.S., Maher, N.M., and Yun, J.W., 1999, Pockmarks Along the California Continental Margin: Implications for Fluid Flow, *Amer. Assoc. of Petroleum Geologists Pacific Section Annual Convention, Abstracts Volume*, p. 28-29.

Gardner, J. V., Dartnell, P. Mayer, L. and Hughes-Clarke, J., 1998, Continental Margin gullies, channels, and canyons: First-order controls from quantitative bathymetry. *SEPM-IAS Research Conference STRATCON Strata and Sequences on Shelves and Slopes, Program and Abstract Vol.*

Kilbourne, K.H., Field, M.E., Gardner, J.V., Jenkins, C., 1999, A new method for variable scale benthic habitat description. *Proceedings, 1999 Monterey Bay National Marine Sanctuary Sanctuary Currents Symposium*, p12, Seaside, CA

Mayer, L.A., Paton, M. Gardner, J., and Ware, C., 1998, Interactive 3-D visualization of multibeam sonar and other data: Seeing is believing. *abs. American Geophysical Union Fall Mtg.* P. F818.

Orange, D.L., Field, M.E., Gardner, J., Driscoll, N., and Mayer, L., 1998, High Resolution Seismic Images of Stacked Transgressive Sequences Proximal to an Active Fault on the Northern California Margin. *EOS Transactions*, 79 (45)

Spinelli, G.A., Field, M.E., Gardner, J.V., and Prior, D. (1998) The Roles of Tectonics and Sediment Dispersal in the Distribution and Preservation of Post-Lowstand Deposits. *EOS Transactions*, 79 (45), F497.

Storlazzi, C.D. and Field, M.E., 1998. The role of antecedent topography and oceanographic forcing on the distribution and transport of littoral sediments along the Monterey Peninsula and Carmel Bay, California, *Eos*, v.79, no. 45 (supplement), American Geophysical Union 1998 Fall Meeting Abstracts, p. 451.

Yun, J.W., Field, M.E., Foland, S.S., Orange, D.L., and Moore, J.C., 1999, Gas Occurrence from the Subsurface to the Water Column: An Integrated Study in the Offshore Eel River Basin, CA, *Amer. Assoc. of Petroleum Geologists Pacific Section Annual Conv., Abstracts Volume*, p. 47.

Yun, J.W. and Foland, S.S., 1998, Varying Structural and Stratigraphic Character Offshore Northern California, *American Geophysical Union 1998 Fall Meeting; Eos, Transactions*, vol. 79, no. 46 Suppl.